Molluscan Research **20(1):** 11-16 *(1999)*

Effects of spatial and temporal changes in water velocity on the density of the freshwater snail *Potamopyrgus antipodarum* (Gray)

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Abstract

The effects of spatial and temporal changes in water velocity on the introduced freshwater snail *Potamopyrgus antipodarum* (Gray) (Gastropoda: Hydrobiidae) were studied in an artificial stream and in Main Creek, Victoria, Australia. The water velocity at which *P. antipodarum* became dislodged in the artificial stream was in agreement with their distribution in Main Creek. In Main Creek the density of *P. antipodarum* on a standard substrate (half bricks) was negatively correlated with water velocity. However, no evidence was found that increases in water velocity associated with floods affect the densities of *P. antipodarum*.

Key words: water velocity, density, *Potamopyrgus antipodarum*

Introduction

Stream ecologists have long considered that the velocity of flowing water influences macroinvertebrate populations in lotic systems (Dittmar, 1955; Dorier, and Valliant, 1955; Hynes, 1970). The nature of the flow environment varies both spatially and temporally (Ward, 1992) and at many scales (Minshall, 1988). This study investigates the effect of spatial and temporal changes in water velocity on the freshwater snail *Potamopyrgus antipodarum*. Specifically, we examine whether *P. antipodarum* density is affected by spatial variation in water velocity and by floods. We hypothesise that in areas of high water velocity *P. antipodarum* is physically removed from the substratum by the force of the moving water. We test this hypothesis by a combination of field and laboratory observations.

Materials and Methods

The study was conducted in Main Creek, a small unregulated stream located approximately 80 km from Melbourne, Victoria, Australia, in a south eastern direction, at a site where it is crossed by Boneo Road (38°29'S, 144°55'E).

Velocities that dislodge P. antipodarum

Using the artificial stream described by Horne and Bennison (1987), tests were carried out to determine the velocity at which *P. antipodarum* were dislodged from the substratum. The velocity at which a snail became dislodged and entered the drift was regarded as the maximum velocity which that individual could withstand.

A single *P. antipodarum* was placed on a small patch of fine sandpaper fixed to the bottom of the channel. The sandpaper was used to provide a more 'natural' substratum than the plexiglass of the channel. Once the *P. antipodarum* had attached to the sandpaper, the velocity was gradually increased from zero until maximum velocity was obtained or the *P. antipodarum* became dislodged. At this point the water velocity was measured with a digital Nixon flow-meter with a propeller diameter of 8 mm. Dislodged snails were caught in a net and their length, width and live mass measured. Ten replicate *P. antipodarum* were tested.

The 'riffle-scale' relationship between the density of P. antipodarum and velocity.

At the scale of a riffle, density of *P. antipodarum* on 62 half bricks and bottom velocity were related by standard correlation. The bricks were used as standard substrate to prevented observations being confounded with different substrata occurring with different water velocities.

The bricks were conditioned for algae by leaving them in Main Creek for approximately two months. The experiment would have been confounded if algae that favour specific velocities (see Power and Stewart, 1987) were present in Main Creek. To avoid this, the bricks were moved, in a haphazard manner, before the experiment so that bricks conditioned at a certain velocity were not necessarily exposed to the same velocity in the experiment. So that all bricks were independent of each other, they were at least 0.5 metres from all neighbouring bricks.

The number of *P. antipodarum* per half brick was counted in the field with the aid of a viewing box on two occasions. The water velocity was measured on top of the brick with a Marsh-McBirney magnetic flow-meter (which measures the water velocity at 1.8 cm above the substrate). The depth of the brick was measured with a ruler and the distance from the bank estimated. The amount of turbulence was visually assigned an ordinal score of 1, 2 or 3. The turbulence index, the water depth and the distance to the bank were used to take into account these potentially confounding factors in a multiple regression equation.

'Smaller-scale' relationship between the density of P. antipodarum and velocity

The relationship between water velocity and *P. antipodarum* density on the scale of an individual half brick was investigated. The numbers of *P. antipodarum* on each of the five visible sides of the 62 half bricks were counted with the aid of a viewing box and velocities on each side were measured using a Nixon flow-meter with the velocity measured closer to the substrate (0.8 cm above the substrate). The null hypothesis was that there is no relationship between the number of *P. antipodarum* per brick side and the water velocity. If correct, there would be an equal number of bricks with negative and positive correlations between density of *P. antipodarum* and velocity. For each brick it was determined whether the slope of the least squares regression line (n=5) was positive or negative and the difference in the observed and the expected relationships for all bricks was assessed in a chi squared test.

The effect of floods on P. antipodarum

The effects of floods on the density of *P. antipodarum* was investigated in September 1993 by taking 9 randomly located replicate samples per sampling episode with an electric suction sampler (Brooks, 1995) from a riffle in Main

Creek before and during three floods occurring close together. Samples were preserved and *P. antipodarum* were counted under a dissecting microscope. A pilot study suggested that 9 replicate samples would be sufficient to gain reasonable power. The null hypothesis was that the flood would have no effect on the density of *P. antipodarum*.

The flood sequence consisted of three closely spaced small floods at an increasing intensity. The 'before flood' sample was taken about 7 days before the first flood when discharge was estimated to be 0.14 $m^3.sec^{-1}$. The 1st (and smallest) flood had an estimated discharge of 0.51 $m^3.sec^{-1}$, the 2nd flood 0.59 $m^3.sec^{-1}$ and the 3rd (and largest) flood 2.1 $m^3.sec^{-1}$. In addition to the sampling before and during the floods, samples were taken after the final flood to monitor any recovery. The 'recovery' (or after) samples were collected 3, 6, and 8 days after the largest flood.

Additionally, non-destructive measurements of *P. antipodarum*, with the aid of a viewing box, on 49 half bricks were made before (day 1) and after (day 4) a separate small flood (estimated discharge 0.60 $m^3.sec^{-1}$).

Results

Dislodgment of P. antipodarum

The minimum and mean velocities at which *P. antipodarum* were dislodged in the artificial stream were 15 and 67.6 ± 8.3 $cm.sec^{-1}$, respectively. However a single *P. antipodarum* remained attached at the maximum velocity that could be produced in the artificial stream 95.4 $cm.sec^{-1}$.

There was no significant linear correlation between the velocity at which a *P. antipodarum* was dislodged and its length, width, length:width ratio or live mass and there was no obvious non-linear correlation (by inspection of scatter plots).

Correlations between water velocity and P. antipodarum density on the bricks

There were significant negative correlations between the log number of P. antipodarum per half brick and the bottom velocity (range 0 to 120 $cm.sec^{-1}$) for both days ($r=-0.431$, $P<0.001$; $r=-0.404$, $P=0.001$, respectively) (Figure 1). Using multiple regression to take into account the effect of depth, distance from the bank and turbulence, these relationships were still significant ($b_1=-0.008$, $P=0.017$; $b_1=-0.007$, $P=0.027$, respectively).

At the smaller scale of an individual side of a half brick, there were significantly more bricks observed with negative relationships than positive relationships between *P. antipodarum* density and velocity than would be expected by chance (chi sq=4.569, df=1, $P<0.01$).

The effect of floods on P. antipodarum

During the peak of the flood mean water velocity reached 94 ± 16.6 $cm.sec^{-1}$. However there was no significant difference in *P. antipodarum* density at the different sampling episodes ($F=2.013$, df= 6 & 56, $P=0.079$, $\beta = 0.307$) (Figure 2). A planned comparison showed no significant difference in the mean density between before flood and during or after the largest flood sampled ($F=1.890$, df=1 & 56, $P=0.175$).

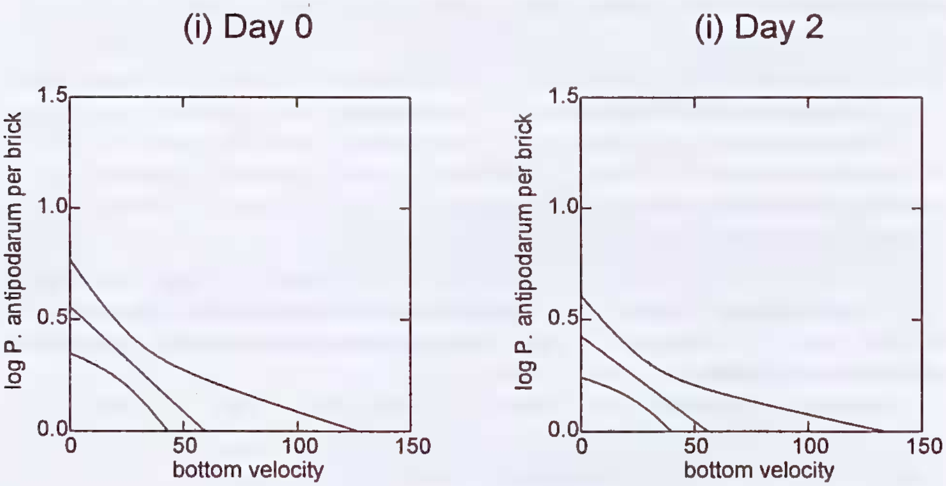

Figure 1.
Scatter plots of log *P. antipodarum* density on half bricks and bottom velocity (cm/sec) on (i) Day 0 and (ii) day 2. The lines are least square regression lines.

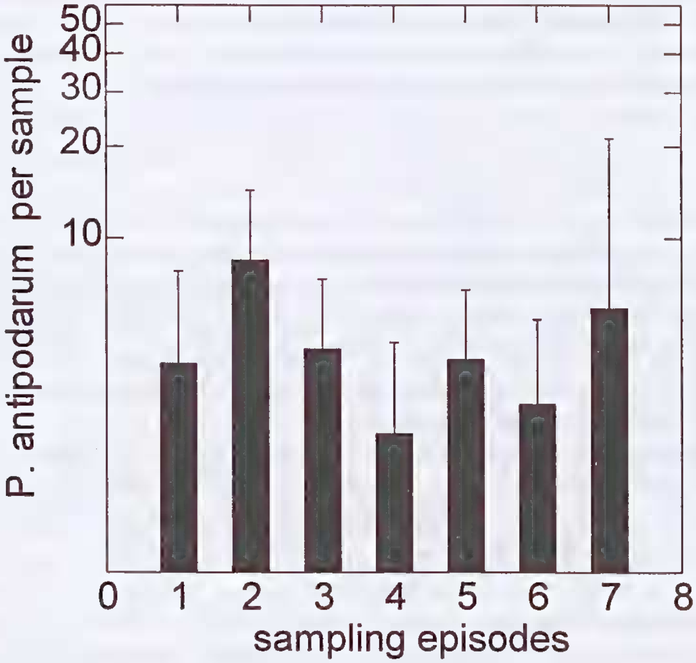

Figure 2.
The relationship between *P. antipodarum* per sample before, during and after a flood sequence, where 1= before flood, 2= during the smallest flood, 3= during the medium level flood, 4= during the larger flood, 5= day 3 after the largest flood, 6= day 6 after the largest flood and 7= day 8 after the largest flood.

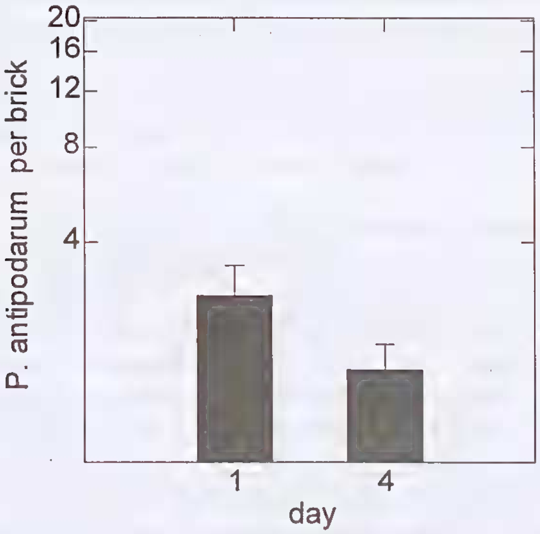

Figure 3.
P. antipodarum per visible portion of half bricks before (=1) and after (=4) a small flood. Error bars are the standard error of the mean.

Similarly, there was no significant difference in the mean log number of *P. antipodarum* per half brick between before and after the flood (F=2.120, df=1 & 42, P=0.153) (Figure 3).

Discussion

At both the spatial scales investigated, the effect of fast moving currents on *P. antipodarum* appeared to be similar. Density of *P. antipodarum* and bottom water velocity were negatively correlated at both the spatial scales investigated, riffle and half brick. In the artificial stream, the mean water velocity at which *P. antipodarum* was dislodged was 67.6 ± 8.3 cm.sec^{-1}. This is in broad agreement with observations in Main Creek where *P. antipodarum* was not observed on the half brick in water velocities above 50 cm.sec^{-1}. The higher value obtained in the artificial stream is probable related to *P. antipodarum* being exposure to higher water velocities for longer in Main Creek than the artificial stream (Holomuzki and Briggs, 1998).

Correlations do not imply causality due to the potential for confounding factors. Measures of water velocity are well known to be confounded by other factors (Ward, 1992). However, by using bricks some potentially confounding factors were eliminated and others were taken into account and, combined with the artificial stream result, suggest that *P. antipodarum* density is being reduced by high water velocity physically forcing them off the substrata.

Why would *P. antipodarum* densities be reduced in areas of fast flowing water while during floods, which are characterised by fast flowing water, their densities would be unaffected? The answer to this question may be that different processes are occurring between temporal and spatial changes in water velocity. If the lack of *P. antipodarum* in areas of high water velocity is caused by the force of the current physically removing *P. antipodarum*, at first thought one would expected that temporal increases in water velocity would remove *P. antipodarum* from their substrate. However, as water velocity increases during the onset of a flood, *P. antipodarum* may be able to detect the rise in water velocity and move to refuges. This explanation is supported by Holomuzki and Birggs (1988) who found that *P. antipodarum* sought crevices during experimental increases in water velocity.

Even if *P. antipodarum* are forced off their substrate by rising water velocity during floods, it does not necessarily follow that floods will reduce the densities of *P. antipodarum* at a given site. Mortality of *P. antipodarum* dislodged from substrate has been observed to be low (2 - 5%) (Holomuzki and Biggs, 1988). So within a site, a flood may wash *P. antipodarum* downstream but live *P. antipodarum* that have themselves been washed away upstream may be deposited in eddies and backwaters at that site. The change in density of *P. antipodarum* at a site following a flood may depend on the number that are exported and the number that are imported. Thus, in a given area, a flood may result in the density of *P. antipodarum* increasing, decreasing or staying constant. This is in agreement with Holomuzki and Birggs (1988) who noted that flow disturbance seemed to affect *P. antipodarum* more by displacement than by killing them.

Acknowledgments

This study was performed as part of an Honours project at Monash University (Clayton). We would also like to thank Gerry Quinn and Barbara Downes for statistical advice, Sabine Schreiber for comments on the manuscript, Alena Glaister for taxonomical advice; we also thank Garry Bennison, Kumar Eliezer and Jeremy (Jerry) DeSilva for the use of, and technical help with, the artificial stream, and finally all who helped with field work.

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